

Technological Transfers, Limited Commitment and Growth

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Abstract

Evidence shows that there are substantial rich-to-poor international capital flows although not as abundant as differences in rates of return would suggest. These flows are procyclical: abundant in good times and scarce in bad times. Conventional growth models face certain difficulties in accounting for this pattern. In this paper, we propose a dynamic model of capital flows to developing countries which is qualitatively consistent with these empirical regularities. The model is based on three main premises: i) international lending contracts are imperfectly enforceable; ii) access to the international financial markets results in technological transfers to a developing country from the rest of the world; iii) some of the productivity gains associated with the access to external financing are perishable. We solve for transitional dynamics of the model economy with endogenously incomplete markets and compare the results with the solutions obtained from the perfect risk-sharing and autarkic environments. Our findings suggest that technological transfers may play a role of an important enforcement mechanism. In our framework, existence of substantial rich-to-poor capital flows is not inconsistent with the presence of default risk.

Keywords: Incentive compatibility, technological diffusion, international capital flows, default risk, numerical algorithm

JEL classification: C63, F34, O33, O40

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1. Introduction

Several features concerning levels and volatility of international capital flows have been documented in the literature. First, international capital flows from the capital-rich to the capital-poor countries are too scarce in view of enormous differences in rates of return.¹ Second, there are substantial private capital flows to the developing countries.² Third, access of the capital-poor countries to the international financial markets has been reported to promote growth and stability in some cases but merely augment instability in the others.³ Fourth, the net capital inflows are procyclical in most developing countries.⁴ Conventional growth models have been reported to face certain difficulties in accounting for the observed pattern of capital flows from the industrialized to the low- and middle income countries.

In this paper we propose a dynamic model of capital flows to low- and middle income countries which is qualitatively consistent with these empirical regularities. Our benchmark is a stochastic growth model with two productive sectors one of which may enjoy productivity benefits associated with the access to external financing. We focus on the institutional aspects of the economy and consider environments which differ in the extent to which the international borrowing contracts are enforceable. To do so, we solve for transition dynamics of the model economy with endogenously incomplete markets and compare the results with the solutions obtained from the perfect risk-sharing and autarkic environments. In addition, we examine the role of alternative assumptions about the severity of the repudiation punishment and their implications for growth, welfare and borrowing patterns.

A number of explanation have been offered in the literature on 'Lucas paradox' of why capital does not flow from rich to poor countries.⁵ Yet, the evidence presented by Reinhart et al. (2003)

¹The evidence on what Lucas (1990) argued to be a puzzle, has been reported by Reinhart and Rogoff (2004) and Lane (2004), among others.

² For instance, according to UNCTAD (1994, 2001) Foreign Direct Investment (FDI) inflows to developing countries increased from an annual average of \$13.1 billion for 1981–1985 to \$240.2 billion in 2000. Some researchers, as e.g. Albuquerque (2003, p. 354), tend to conclude that "International private capital flows represent a major source of financing economic activity in developing countries".

³The World Bank's *Global Development Finance* (2001, p. 71) report concludes that "although opening up domestic financial markets to international competition has attracted more capital to developing countries and has bolstered growth in some, the larger volume of capital market transactions has also contributed to a more volatile climate". An extensive review of the empirical evidence on the topic under a suggestive title: "Volatile International Capital Flows: A Blessing or a Curse?" is provided by Kaminsky (2004).

⁴Kaminsky et al. (2004) report empirical evidence on this phenomenon which they name "When it Rains, it Pours".

⁵For instance, Barro et al. (1995) discussing international capital mobility in a neoclassical growth model exoge-

and Reinhart and Rogoff (2004, p. 53) tends to suggest that "some explanations may be more relevant than others". They argue that

"...the key explanation to the "paradox" of why so little capital flows to poor countries may be quite simple: Countries that do not repay their debts have a relatively difficult time borrowing from the rest of the world" (Reinhart and Rogoff, 2004, p. 56).

This is the avenue we will follow in this paper. Hence, our point of departure is that international lending contracts are imperfectly enforceable. In the absence of supranational authority, the available enforcement mechanisms are limited to a threat of exclusion from the international markets. Hence, instead of exogenously limiting the amount of capital the developing countries may borrow, we incorporate a friction which allows to a recipient country to borrow to the extent it will be willing to repay later on. Another rationale for relying on this assumption is that countercyclical capital inflows would be predicted both by theories of exogenously constrained access to the world credit markets and by theories of perfect capital mobility (Lane, 2004).

As argued by Albuquerque (2003) an open question which deserves attention in the context of the models with imperfect enforcement is the one concerning the levels of international capital flows. The reason is that the models of international lending under limited commitment which allow for capital accumulation in the autarky such as those of Marcet and Marimon (1992) and Kehoe and Perri (2002) have very dramatic quantitative implications for international capital mobility. In words of Albuquerque (2003, p. 380) "these models provide an answer to Lucas' (1990) question, but an extreme one". They show that enforcement constraints result in negligible international capital flows both along the transition path and at the steady state distribution. The latter result is less than satisfying in view of the recent evidence on capital flows to developing countries. This is the issue we are going to address in this paper.

One of the reason for this failure is that the defaulter's punishment is not severe enough. This might stem from the failure of the existing theories of capital mobility under limited enforcement to model certain margins. The margin we argue to be important is presence of technological transfers a developing country will enjoy as a consequence of an access to the international markets. By the very nature of technology, that is its partial excludability, the recipient country will not be

nously limit the types of capital which can be financed by borrowing on the world market.

able to enjoy all the benefits associated with foreign technology should it switch to autarky. This feature makes the defaulter's punishment more severe, as compared to those used by Marcet and Marimon (1992) or Kehoe and Perri (2002). In the context of our model, this default punishment will introduce a wedge between steady state distributions corresponding to the environment with imperfect enforcement of international lending contracts and the autarky. Whether this will generate non-negligible capital inflows to an economy during its transition from a low level of capital towards its ergodic distribution is the question which we will consider in this paper.

Hence, the second premise of our framework is that access to international financial markets is associated with increased efficiency of production in some sectors of the developing economy. This increase in productivity originates from the transmission of technologies from the industrialized world to the developing country which enjoys what Gerschenkron (1952) referred to as an 'advantage of backwardness'. A substantial amount of research has documented empirically the role of international capital flows for technological diffusion. Some studies emphasize the positive effect on productivity of openness and free capital movement *per se*. For example, Frankel and Romer (1999) argue that the benefits from integration for a developing country partially stem from the transfer of ideas from the rest of the world. In line with that the World Bank (2001, p. 59) *Global Development Finance* annual report states that there is ample evidence indicating towards the productivity benefits of the capital flows "through transfer of technology and management techniques". In a recent study, Alcalá and Ciccone (2004) provide empirical evidence indicating that openness promotes growth through its effect on TFP.

Other studies stress the importance of FDI as a mechanism of technological transfers to the developing countries from the rest of the world. For instance, according to World Bank (2001) FDI has been positively associated with the productivity of the foreign owned firms and with positive spillover to domestically owned firms.⁶ Romer (1993) suggests that FDI has considerable potential to transfer ideas from the industrialized countries to the developing countries. FDI as a potential mechanism of technological transfers has been particularly emphasized due to its increasing role in the stream of international capital flows to low- and middle income countries. As documented by Thomas and Worrall (1994) already in the mid-eighties about a half of all capital flows to the

⁶Görg and Strobl (2001) provide a comprehensive review of the empirical literature on FDI and productivity spillovers. They also give account of other channels through which productivity spillovers occur such as movement of highly skilled personnel, the 'demonstration effect' or the 'competition effect'.

developing countries took form of FDI. The fraction of FDI in the international capital flows kept increasing during the last two decades. Moreover, according to IMF (2003) it now constitutes the most important net flow for all regions.

Our final premise is that the recipient country will not be able to fully, if at all, enjoy the productivity benefits should it be excluded from the international markets. To some extent, this feature of the model can be motivated by an inherent property of technology - its partial excludability. Similar assumptions have been used by Cohen and Sachs (1986) and Eaton and Gersovitz (1984) who assume that foreign debt repudiation results in permanent loss of productive efficiency associated with foreign technology.

We consider a model with two agents, one risk-averse agent representing a developing country and the other risk neutral agent representing the rest of the world. We focus on the growth of the developing country which is assumed to have low initial level of capital. In this context, growth is understood as a transition from the initial low level of capital towards the steady state distribution. We analyze the model within three environments which differ in the extent to which the international lending contracts are being enforced. These are: (i) autarky; (ii) external financing with perfect enforcement of contracts; and (iii) external financing with limited enforcement of contracts. Under the latter regime, a developing country may at any moment appropriate the accumulated capital and refuse to honor its debt. In this case it will suffer a default punishment which will involve loss of any external financing opportunities in the future.

We assume that there are two productive sectors in the economy, which we refer to as domestic and foreign operated sector. Each of the sectors has Cobb-Douglas technology. The risk averse agent decides how much to invest in each of the sectors. The technology which converts investment into capital goods is non-linear and affected by the productivity shocks. The foreign sector is assumed to be more productive due to technological transfers associated with external financing⁷. Failure to honor the external debt results in permanent loss of productivity benefits associated with foreign technology.

We consider two modifications of the model which differ in the default punishment a developing country will endure should it refuse to honor its contractual obligations. First, we analyze a model

⁷This assumption relies on the empirical evidence reviewed by Görg and Strobl (2001) who document that in the literature it is often argued that the positive spillovers only affect certain sectors of the economy.

where in case of debt repudiation the country loses not only productivity benefits in the foreign operated sector but also accumulated capital in this sector. Furthermore, the country is deprived of the possibility to develop this sector on its own. Similar assumption has been used by Marcet and Marimon (1998), where they consider a partnership with limited commitment, and Albuquerque (2003), who studies composition of international capital flows. Under this assumption, the autarkic environment, which is hereafter referred to as one-sector autarky, is similar to the stochastic growth model of Brock and Mirman (1972) augmented with non-linear stochastic investment technology. Our key finding from this model is that perishable technological gains from external financing opportunities may eliminate the default risk even though they affect only some sectors of the economy.

The discussed above assumption of the punishment is case of deviation from the optimal plan may be judged as extremely severe. Indeed, the defaulting country loses not only all the productivity benefits and capital accumulated in the foreign operated sector but also a possibility to develop this sector on its own. Although, the latter cannot be ruled out as completely unrealistic⁸, this feature is not especially attractive in our setting since our model economy consists of merely two productive sectors. Therefore, we consider a framework where in case of debt repudiation the developing country loses the technological advantage associated with access to external financing. However, the capital stock in all sectors of the economy remains productive with the TFP level of the domestically operated sector. Relying on this assumption we consider three representative cases which differ in the extent of the technological diffusion.

We overcome the difficulty that the models of sustained growth have in explaining the rich structure of observed capital flows and borrowing patterns across low- and middle-income countries. Our framework suggests that under limited enforcement the pattern of capital movements depends heavily on the perishable productivity benefits associated with the external financing opportunities.

From a theoretical perspective, our findings allow to conclude that the existence of substantial capital flows from the developed to developing countries is not inconsistent with the presence of the default risk. We also conclude that technological transfers may play a role of an enforcement mechanism. In our framework even moderate technological benefits associated with external financing

⁸For instance, former soviet republics, after defaulting on the risk-sharing agreement with Russia known as USSR, might face serious difficulties should they intent to develop uranium enrichment and associated sectors.

opportunities may substantially reduce the negative effect on the welfare of the failure to perfectly enforce contracts. Presence of technological diffusion in the environment with limited commitment induces a developing country to use foreign capital to both smooth consumption and invest more heavily in all the sectors of the economy including those directly unaffected by the technological transfers. The latter results in faster growth and significant welfare gains.

Our framework presents a case for capital controls. Contrary to Albuquerque (2003), the normative implications of our model do not advocate discouraging debt flows or encouraging FDI flows to the developing countries. Our claim is that lenders should encourage those capital inflows which are associated with perishable TFP benefits. These might include FDI in the sectors which depend on foreign blueprints or intangible assets, such as managerial skills.

Since we study models with dynamic participation constraints, which involve expected values of the future control variables, we are unable to use the results of standard dynamic programming. Our methodology relies on the contribution of Marcet and Marimon (1998) who have demonstrated that problems with incentive compatibility constraints fall into a general class of problems, which can be cast into an alternative recursive framework. Our numerical analysis utilizes the parameterized expectation approach (PEA) originally proposed by Marcet (1989). A particular version of simulation PEA which we use allows us to handle occasionally binding inequality constraints involving conditional expectations of the future choice variables.

Although PEA algorithm approximates the true equilibrium at the steady state distribution with arbitrary accuracy, the policy function obtained from the long-run simulations may not be a good approximation for the solution during the initial periods. This is of particular importance for our analysis since we consider an economy during the transition towards the steady state distribution. To overcome this problem we use a version of PEA featuring exogenous oversampling in order to find a distinct policy function for the initial periods.

Another non-standard feature of the problem we are solving is that the optimality condition in the limited enforcement environment involve partial derivatives of the value function associated with recursive formulation of the dynamic problem the agent faces in case of debt repudiation. In order to handle this issue, we utilize an algorithm proposed in Dmitriev (2006) to numerically compute partial derivatives of the value function with respect to several endogenous state variables.

The rest of the paper is organized as follows. Section 2. presents the baseline models corre-

sponding to the three environments: one-sector autarky, external financing with full and limited enforcement. These models rely on the most stringent assumption about the defaulter's punishment. Section 3. describes the numerical algorithms for solving the models and analyzes the solutions for them. Section 4. introduces the main model with two-sector autarky which relies on a more moderate assumption concerning the debt repudiation punishment. Section 5. analyzes the numerical solutions corresponding to the models with two-sector autarky which differ in the magnitude of perishable productivity gains. Section 6. concludes.

2. The Baseline Model

The environments considered in the paper essentially share some features. There are two agents: agent 1 who is risk averse and can be interpreted as a developing country and agent 2 who is risk neutral and represents the industrialized countries. As in Marcet and Marimon (1992) the technologies that convert investment into capital are non-linear and are affected by a productivity shock.

2.1. *Efficient growth mechanism under full commitment*

It is assumed that there are two sectors in the economy which will be called domestic and foreign operated sector. In the case of external financing due to technological transfers the foreign operated sector will enjoy higher productivity as compared with the domestic sector.⁹ The set of firms which are affected by the technological transfers from the rest of the world will be referred to as foreign operated sector.

In this environment, the efficient growth mechanism, Γ , represents a state-contingent investment and transfer plans $\Gamma = \{i_{1t}, i_{2t}, \tau_t\}$ which is obtained as a solution to a dynamic principal-agent problem for a given set of initial conditions and weights. The latter are comprised of the initial capital stocks k_{10}, k_{20} , the initial productivity shock θ_0 , and the weight $\lambda \in \mathbb{R}_+$ assigned to the risk-averse agent in the planner's problem given by

⁹The technological transfers partially originate from the fact that a part of capital inflows into a country will take form of FDI. It is often argued in the literature that the positive spillovers from FDI only affect certain firms in the domestic economy Görg and Strobl (2001).

Program 1

$$\max_{\{c_{1t}, \tau_t, i_{1t}, i_{2t}\}_{t=0}^{\infty}} E_0 \left[\sum_{t=0}^{\infty} \beta^t [\lambda u(c_{1t}) + (-\tau_t)] \right]$$

subject to

$$c_{1t} - \tau_t + i_{1t} + i_{2t} = f(k_{1t}) + F(k_{2t}), \quad (1)$$

$$k_{1t+1} = (1 - \delta)k_{1t} + g(i_{1t}, \theta_{t+1}), \quad (2)$$

$$k_{2t+1} = (1 - \delta)k_{2t} + g(i_{2t}, \theta_{t+1}), \quad (3)$$

with $c_{1t} \geq 0, i_{1t}, i_{2t} \geq 0, k_{10}, k_{20}, \theta_0$ given.

In this specification $u(\cdot)$ represents the instantaneous utility of the risk-averse agent. We denote as $f(\cdot)$ and $F(\cdot)$ the production functions corresponding to the domestic and foreign operated sectors of the economy. The function that transforms units of investment into units of capital is denoted as $g(\cdot)$. The consumption of the risk-averse agent is given by c_{1t} , the transfers from the risk-neutral agent to the risk-averse one are denoted by τ_t . Investment in to the two sectors are given by i_{1t} and i_{2t} , and the corresponding capital stocks by k_{1t} and k_{2t} . The variable θ_{t+1} represents an exogenous stochastic shock, the realization of which is unknown at the time the investment decisions are made.

The following assumptions, relatively standard in the stochastic growth literature, will hold throughout the rest of the paper¹⁰: (i) the utility function $u(\cdot)$ of the agent 1 is strictly concave, twice differentiable and satisfies the Inada conditions: $\lim_{c \rightarrow 0} u'(c) = +\infty, \lim_{c \rightarrow \infty} u'(c) = 0$; (ii) the sectorial production functions $f(\cdot)$ and $F(\cdot)$ are concave and differentiable; (iii) the exogenous stochastic process θ_t is stationary and has bounded support; (iv) depreciation rate $\delta \in [0, 1]$; (v) $g(\cdot, \theta)$ is differentiable and concave.

A note on the interpretation of this model should be made. As in the model of Acemoglu and Zilibotti (1997) the development takes the form of the capital accumulation in the existing sector considered as domestic as well as opening and subsequent accumulation in a new sector in the economy considered as foreign operated. The extent of the development in the domestically operated sector is summarized by the capital stock k_{1t} . Likewise the extent of the development in the foreign operated sector is summarized by the capital stock k_{2t} an initial value of which is lower than that of the domestic sector.

¹⁰Similar assumptions appear in Marcet and Marimon (1992), and Jones and Manuelli (1990), among others.

In addition to the equations (1), (2) and (3) the solution to the Program 1 must satisfy the following first order conditions:

$$1 = \beta E_t \left[\frac{\partial g(i_{1t}, \theta_{t+1})}{\partial i_{1t}} \sum_{j=0}^{\infty} (\beta(1-\delta))^j f'(k_{1t+1+j}) \right], \quad (4)$$

$$1 = \beta E_t \left[\frac{\partial g(i_{2t}, \theta_{t+1})}{\partial i_{2t}} \sum_{j=0}^{\infty} (\beta(1-\delta))^j F'(k_{2t+1+j}) \right], \quad (5)$$

$$u'(c_{1t}) = \lambda^{-1}. \quad (6)$$

The model discussed above is based on the assumption that the planner can perfectly enforce both parties to follow the plan. In the remaining of the paper, this assumption will be relaxed and a number of assumptions regarding incentive compatibility will be considered. These assumptions will essentially differ in the extent of the punishment the risk-averse agent would have to endure should he deviate from the plan.

2.2. Efficient growth mechanisms under limited commitment

We begin with the most stringent assumption on the punishment in case of violation of the contract. We will assume that in case of default the developing country will appropriate the capital stock corresponding to the domestically operated sectors k_{1t} . The newly opened foreign sector will no longer be productive. This assumption can be justified on the grounds that the newly opened sector can be totally dependent on the technology and managerial skills transferred from the industrialized world.¹¹

Hence, the failure to honor the contract will result in closing down the sector which cannot be operated using domestically available technologies. In case of debt repudiation, the country will switch to autarky and will remain excluded from the international markets forever. The problem the country would face in autarky takes the following form:

$$\max_{\{c_t, i_t\}_{t=0}^{\infty}} E_0 \left[\sum_{t=0}^{\infty} \beta^t u(c_t) \right]$$

¹¹ A similar assumption has been considered by Marcet and Marimon (1998) and Albuquerque (2003).

subject to

$$c_t + i_t = f(k_t),$$

$$k_{t+1} = (1 - \delta)k_t + g(i_t, \theta_{t+1}),$$

where $c_t \geq 0, i_t \geq 0$, and the initial values k_0, θ_0 are given by the corresponding values of capital stock of the domestically operated sector and the shock value at the time of deviation. Using the arguments of standard dynamic programming one can show existence of the time invariant policy functions $i(k, \theta)$, $c(k, \theta)$ and a value function $V^a(k, \theta)$. Hence, the reservation value for the risk-averse agent at time t is the utility of the autarkic solution $V^a(k_{1t}, \theta_t)$ given the capital stock k_{1t} and the productivity shock θ_t . The optimal allocations can be found by solving the following planner's problem with $\lambda \in \mathbb{R}_+$ and the participation constraint imposed on agent 1:

Program 2

$$\max_{\{c_{1t}, \tau_t, i_{1t}, i_{2t}\}_{t=0}^{\infty}} E_0 \left[\sum_{t=0}^{\infty} \beta^t [\lambda u(c_{1t}) + (-\tau_t)] \right]$$

subject to

$$c_{1t} - \tau_t + i_{1t} + i_{2t} = f(k_{1t}) + F(k_{2t}), \quad (7)$$

$$k_{1t+1} = (1 - \delta)k_{1t} + g(i_{1t}, \theta_{t+1}), \quad (8)$$

$$k_{2t+1} = (1 - \delta)k_{2t} + g(i_{2t}, \theta_{t+1}), \quad (9)$$

$$E_t \left[\sum_{i=0}^{\infty} \beta^i u(c_{1t+i}) \right] \geq V^a(k_{1t}, \theta_t), \quad (10)$$

with $c_{1t} \geq 0, i_{1t}, i_{2t} \geq 0, k_{10}, k_{20}, \theta_0$ given.

Since the constraint (10) involves expected values of the future variables, Program 2 is not a special case of the standard dynamic programming problems, and the Bellman equation will not be satisfied. However, as shown by Marcet and Marimon (1998) this problem falls into a general class of problems, which can be cast into alternative recursive framework. The recursive saddle point problem associated with Program 2 will be given by

$$\begin{aligned} \max_{\{c_{1t}, \tau_t, i_{1t}, i_{2t}\}_{t=0}^{\infty}} \min_{\{\mu_t\}_{t=0}^{\infty}} \mathcal{H} &= E_0 \sum_{t=0}^{\infty} \beta^t \{(\lambda + M_{t-1}) u(c_{1t}) + (-\tau_t) \\ &\quad + \mu_t (u(c_{1t}) - V^a(k_{1t}, \theta_t))\} \end{aligned} \quad (11)$$

subject to (7)-(9) and

$$M_t = M_{t-1} + \mu_t, \quad M_{-1} = 0, \quad (12)$$

$$\mu_t \geq 0.$$

Indeed, the corresponding Lagrangian is

$$\mathcal{L} = E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \lambda u(c_{1t}) + (-\tau_t) + \mu_t \left(E_t \left[\sum_{i=0}^{\infty} \beta^i u(c_{1t+i}) \right] - V^a(k_{1t}, \theta_t) \right) \right\}$$

subject to (7)-(9), given $\mu_t \geq 0$, where $\beta^{-t}\mu_t$ is the Lagrange multiplier of (10) at t . The law of iterated expectations allows to imbed the conditional expectations E_t into E_0 . Furthermore, reordering the terms and introducing the law of motion for M_t yields the above result.

As shown by Marcet and Marimon (1998), under certain assumptions¹² the solution to the recursive saddle point problem obeys a saddle point functional equation. Within our framework their result implies that there exists a unique value function,

$$\begin{aligned} W(k_1, k_2, M, \theta) = & \min_{\mu \geq 0} \max_{\{c_1, \tau, i_1, i_2\}} \{ (\lambda + M) u(c_1) + (-\tau) + \mu (u(c_1) - V^a(k_1, \theta)) \\ & + \beta E [W(k'_1, k'_2, M', \theta') \mid \theta] \} \end{aligned}$$

subject to

$$c_1 - \tau + i_1 + i_2 = f(k_1) + F(k_2), \quad (13)$$

$$k'_j = (1 - \delta)k_j + g(i_j, \theta'), \text{ for } j = 1, 2 \quad (14)$$

$$M' = M + \mu, \quad (15)$$

$$c_1, i_1, i_2 \geq 0, \quad (16)$$

for all (k_1, k_2, M, θ) and such that $W(k_{10}, k_{20}, M_{-1}, \theta_0)$ is the value of Program 2. The policy

¹²Marcet and Marimon (1998) state some interiority conditions needed for the existence of the saddle point problem. These are trivially satisfied in the framework considered here.

correspondence associated with the above saddle point functional equation is given by

$$\begin{aligned} \psi(k_1, k_2, M, \theta) \in \arg \min_{\mu \geq 0} \max_{\{c_1, \tau, i_1, i_2\}} \{ & (\lambda + M) u(c_1) + (-\tau) + \mu (u(c_1) - V^a(k_1, \theta)) \\ & + \beta E [W(k'_1, k'_2, M', \theta') \mid \theta] \} \end{aligned}$$

subject to (13) - (16).

The key results demonstrated by Marcet and Marimon (1998) ensures that the optimal solution of Program 2 satisfies $(c_{1t}, \tau_t, i_{1t}, i_{2t}, \mu_t) = \psi(k_{1t}, k_{2t}, M_{t-1}, \theta_t)$ for all t with the initial conditions $(k_{10}, k_{20}, 0, \theta_0)$. That is there exist a time invariant policy correspondence ψ such that only the values of a small number of past variables $(k_{1t}, k_{2t}, M_{t-1}, \theta_t)$ matter. Hence, the problem is now in a recursive framework the solution to which can now be obtained from studying the saddle point functional equation.

Denoting γ_{1t} and γ_{2t} the Lagrange multipliers of the constraints (8) and (9), the first order conditions for this problem become:

$$(\lambda + M_t) u'(c_{1t}) = 1, \quad (17)$$

$$-1 - \beta E_t \left[\gamma_{jt+1} \frac{\partial g(i_{jt}, \theta_{t+1})}{\partial i_{jt}} \right] = 0, \text{ for } j = 1, 2 \quad (18)$$

$$f'(k_{1t}) - \mu_t \frac{\partial V^a}{\partial k_{1t}}(k_{1t}, \theta_t) + \gamma_{1t} - \beta(1 - \delta) E_t [\gamma_{1t+1}] = 0, \quad (19)$$

$$F'(k_{2t}) + \gamma_{2t} - \beta(1 - \delta) E_t [\gamma_{2t+1}] = 0, \quad (20)$$

$$E_t \left[\sum_{i=0}^{\infty} \beta^i u(c_{1t+i}) \right] - V^a(k_{1t}, \theta_t) \geq 0, \quad (21)$$

$$\mu_t \left[E_t \left[\sum_{i=0}^{\infty} \beta^i u(c_{1t+i}) \right] - V^a(k_{1t}, \theta_t) \right] = 0, \quad (22)$$

in addition to the technological constraints (7)-(9), the law of motion (12) for the co-state variable M_t , and non-negativity of the Lagrange multiplier $\mu_t \geq 0$.

3. Solutions to the Growth Models

In this section we will present the numerical solutions for various models of this paper as well as describe the algorithms for obtaining them. To obtain the numerical solution to the models we will rely on the parameterized expectation approach. With some exceptions, the functional forms utilized here are similar to those of Marcet and Marimon (1992). These are

$$f(k_{1t}) = Ak_{1t}^\alpha \text{ and } F(k_{2t}) = \tilde{A}k_{2t}^\alpha,$$

$$g(i_t, \theta_{t+1}) = a(\theta_{t+1} + s) \frac{i_t}{(1 + i_t)} + b,$$

$$u(c_{1t}) = c_{1t}^{\gamma+1}/(\gamma + 1),$$

$$\log \theta_t = \rho \log \theta_{t-1} + \varepsilon_t,$$

where $\{\varepsilon_t\}$ are independent normally distributed random variables with zero mean and variance σ_ε^2 .

3.1. Solving the problem with full enforcement

With the chosen functional forms the optimality conditions for the case of full enforcement are the following:

$$(1 + i_{1t})^2 = \beta E_t \left[a(\theta_{t+1} + s) \sum_{j=0}^{\infty} (\beta(1 - \delta))^j A \alpha (k_{1t+1+j})^{\alpha-1} \right], \quad (23)$$

$$(1 + i_{2t})^2 = \beta E_t \left[a(\theta_{t+1} + s) \sum_{j=0}^{\infty} (\beta(1 - \delta))^j \tilde{A} \alpha (k_{2t+1+j})^{\alpha-1} \right], \quad (24)$$

$$c_{1t}^\gamma = \lambda^{-1}, \quad (25)$$

$$c_{1t} - \tau_t + i_{1t} + i_{2t} = Ak_{1t}^\alpha + \tilde{A}k_{2t}^\alpha, \quad (26)$$

$$k_{it+1} = (1 - \delta)k_{it} + a(\theta_{t+1} + s) \frac{i_{it}}{(1 + i_{it})} + b, \text{ for } i = 1, 2. \quad (27)$$

The first step of the PEA is to substitute the conditional expectations in (23) and (24) by the flexible functional forms that depend on the state variables and some coefficients¹³. Each of the

¹³see Marcet and Lorenzoni (1998) for further details on the implementation of PEA.

parameterized expectations $i = 1, 2$ takes the form:

$$\psi(\omega^i; k_{1t}(\omega), k_{2t}(\omega), \theta_t) = \exp(\omega_1^i + \omega_2^i \log k_{1t}(\omega) + \omega_3^i \log k_{2t}(\omega) + \omega_4^i \log \theta_t),$$

where $\omega = (\omega^1; \omega^2)$. The use of the exponential polynomial guarantees that the left hand side of (23) and (24) would be positive. Increasing the degree of the polynomial would allow to approximate the solution with arbitrary accuracy¹⁴.

The algorithm for solving the model takes the following steps:

- (I) Fix the initial conditions and draw a series of $\{\theta_t\}_{t=1}^T$ that obeys the law of motion for the exogenous state variable. The number of periods T in the truncated series should be sufficiently large.
- (II) For a given ω substitute the conditional expectations in (23) and (24) to yield:

$$(1 + i_{it})^2 = \delta \psi(\omega^i; k_{1t}(\omega), k_{2t}(\omega), \theta_t) \text{ for } i = 1, 2 \quad (28)$$

- (III) Using the realizations of θ_t obtain recursively from (28) and (25)-(27) a series of the endogenous variables $\{c_{1t}(\omega), \tau_t(\omega), i_{1t}(\omega), i_{2t}(\omega), k_{1t}(\omega), k_{2t}(\omega)\}$ for this particular ω .
- (IV) The next step involves running two separate non-linear regressions. The role of the dependent variables will be performed by the expressions inside the conditional expectation in the RHS of (23) and (24). Namely, the 'dependent variables' $Y_{1t}(\omega)$ and $Y_{2t}(\omega)$ would take form

$$\begin{aligned} Y_{1t}(\omega) &\equiv a(\theta_{t+1} + s) \sum_{j=0}^{\infty} (\beta(1 - \delta))^j A \alpha(k_{1t+1+j}(\omega))^{\alpha-1}, \\ Y_{2t}(\omega) &\equiv a(\theta_{t+1} + s) \sum_{j=0}^{\infty} (\beta(1 - \delta))^j \tilde{A} \alpha(k_{2t+1+j}(\omega))^{\alpha-1}. \end{aligned}$$

¹⁴The fact that PEA can provide arbitrary accuracy if the approximation function is refined and a proof of convergence to the correct solution are given in Marcet and Marshall (1994). In practice the choice of degree of the exponential polynomial can be guided by the test for accuracy in simulations proposed by den Haan and Marcet (1994). Some practical issues on dealing with higher-order polynomials in the approximation function are discussed in den Haan and Marcet (1990).

Now, letting $S^i(\omega)$ be the result of the following regression:

$$Y_{it}(\omega) = \exp(\xi_1^i + \xi_2^i \log k_{1t}(\omega) + \xi_3^i \log k_{2t}(\omega) + \xi_4^i \log \theta_t) + \eta_{it},$$

for $i = 1, 2$, define $S(\omega) \equiv (S^1(\omega), S^2(\omega))$.

- (V) The final step involves using an iterative algorithm to find the fixed point of S , and the set of coefficients $\omega_f = S(\omega_f)$ which would give the solution for the endogenous variables $\{c_{1t}(\omega_f), \tau_t(\omega_f), i_{1t}(\omega_f), i_{2t}(\omega_f), k_{1t}(\omega_f), k_{2t}(\omega_f)\}$.

3.2. Solving the problem with limited commitment

This section shows how to solve the model with limited enforcement using PEA adapted from Marcet and Marimon (1992). The main difference from the algorithm discussed above is that here the participation constraint might be binding in some periods and slack in the others. Furthermore, there is one more expectation to parameterize and an additional (co-)state variable M_{t-1} to include into the parameterization.

The following optimality conditions are to be satisfied:

$$\mu_t \left[u(c_{1t}) + E_t \left[\sum_{i=1}^{\infty} \beta^i u(c_{1t+i}) \right] - V^a(k_{1t}, \theta_t) \right] = 0, \quad (29)$$

$$E_t \left[\sum_{i=0}^{\infty} \beta^i u(c_{1t+i}) \right] - V^a(k_{1t}, \theta_t) \geq 0, \quad (30)$$

$$c_{1t}^\gamma = 1 / (\lambda + \mu_t + M_{t-1}), \quad (31)$$

$$M_t = M_{t-1} + \mu_t, \quad (32)$$

$$\begin{aligned} (1 + i_{1t})^2 &= \beta E_t \left[a(\theta_{t+1} + s) \sum_{j=0}^{\infty} (\beta(1 - \delta))^j \right. \\ &\quad \times \left. \left(A\alpha(k_{1t+1+j})^{\alpha-1} - \mu_{t+j+1} \frac{\partial V^a(k_{1t+j+1}, \theta_{t+j+1})}{\partial k_{1t+j+1}} \right) \right], \end{aligned} \quad (33)$$

$$(1 + i_{2t})^2 = \beta E_t \left[a(\theta_{t+1} + s) \sum_{j=0}^{\infty} (\beta(1 - \delta))^j \tilde{A} \alpha(k_{2t+1+j})^{\alpha-1} \right], \quad (34)$$

$$c_{1t} - \tau_t + i_{1t} + i_{2t} = A k_{1t}^{\alpha} + \tilde{A} k_{2t}^{\alpha}, \quad (35)$$

$$k_{jt+1} = (1 - \delta)k_{jt} + a(\theta_{t+1} + s)i_{jt}/(1 + i_{jt}) + b, \text{ for } j = 1, 2, \quad (36)$$

in addition to the inequality constraint $\mu_t \geq 0$ and the initial conditions¹⁵.

In order to solve this model with PEA the algorithm described for the case of full enforcement should be modified in the following way. First, in step II parameterize the conditional expectations in (29), (33) and (34) to yield

$$(1 + i_{it}(\omega))^2 = \delta \psi(\omega^i; k_{1t}(\omega), k_{2t}(\omega), M_{t-1}(\omega), \theta_t) \text{ for } i = 1, 2, \quad (37)$$

$$\mu_t [u(c_{1t}(\omega)) + \beta \psi(\omega^3; k_{1t}(\omega), k_{2t}(\omega), M_{t-1}(\omega), \theta_t) - V^a(k_{1t}(\omega), \theta_t)] = 0,$$

where $\omega = (\omega^1, \omega^2, \omega^3)$.

In step III the participation constraint should be taken into account. One way to proceed is to initially assume that the participation constraint is not binding, then $\mu_t(\omega) = 0$, $M_t(\omega) = M_{t-1}(\omega)$, and the solution for $c_{1t}(\omega)$ follows from (31). For this solution one has to check whether the constraint is indeed satisfied, that is if

$$u(c_{1t}(\omega)) + \beta \psi(\omega^3; k_{1t}(\omega), k_{2t}(\omega), M_{t-1}(\omega), \theta_t) \geq V^a(k_{1t}(\omega), \theta_t).$$

If that is the case one can proceed by solving for the rest of the endogenous variables from (37) and the feasibility constraints (35) - (36). Otherwise, the participation constraint must be binding,

¹⁵From (19) and (20) using recursive substitution and the law of iterated expectations yields the following expressions for the lagrange multipliers γ_{1t} and γ_{2t}

$$\begin{aligned} \gamma_{1t} &= \beta E_t \left[a(\theta_{t+1} + s) \sum_{j=0}^{\infty} (\beta(1 - \delta))^j \left(\mu_{t+j} \frac{\partial V^a}{\partial k_{1t+j}}(k_{1t+j}, \theta_{t+j}) - f'(k_{1t+j}) \right) \right], \\ \gamma_{2t} &= -\beta E_t \left[a(\theta_{t+1} + s) \sum_{j=0}^{\infty} (\beta(1 - \delta))^j F'(k_{2t+j}) \right]. \end{aligned}$$

Substituting the the above expressions into (18), and using again the law of iterated expectations and the functional forms for the production and investment functions yields the optimality conditions (33) and (34).

that is

$$u(c_{1t}(\omega)) + \beta\psi(\omega^3; k_{1t}(\omega), k_{2t}(\omega), M_{t-1}(\omega), \theta_t) = V^a(k_{1t}(\omega), \theta_t),$$

from which the solution for $c_{1t}(\omega)$ follows. The value of the multiplier $\mu_t(\omega)$ then follows from (31), the value of $M_t(\omega)$ from the law of motion (32), and the rest of the endogenous variables from (37) and (35) - (36).

Now, step IV will involve running three non-linear regressions for $i = 1, 2, 3$ of the form

$$Y_{it}(\omega) = \exp(\xi_1^i + \xi_2^i \log k_{1t}(\omega) + \xi_3^i \log k_{2t}(\omega) + \xi_4^i \log \theta_t + \xi_5^i M_{t-1}(\omega)) + \eta_{it},$$

where the 'dependent variables' are given by

$$\begin{aligned} Y_{1t}(\omega) &\equiv a(\theta_{t+1} + s) \sum_{j=0}^{\infty} (\beta(1-\delta))^j \left[A\alpha(k_{1t+1+j}(\omega))^{\alpha-1} \right. \\ &\quad \left. - \mu_{t+j+1}(\omega) \frac{\partial V^a(k_{1t+j+1}(\omega), \theta_{t+j+1})}{\partial k_{1t+j+1}} \right], \\ Y_{2t}(\omega) &\equiv a(\theta_{t+1} + s) \sum_{j=0}^{\infty} (\beta(1-\delta))^j \tilde{A}\alpha(k_{2t+1+j}(\omega))^{\alpha-1}, \\ Y_{3t}(\omega) &\equiv \sum_{i=1}^{\infty} \beta^i u(c_{1t+i}(\omega)). \end{aligned}$$

The last step is similar to the one in the the case of full enforcement.

A few notes on the algorithm should be made. First, in this algorithm μ_t will be positive by construction. Second, step IV involves calculation of the derivative of the value function in the autarky with the respect to its first argument. Marcet and Marimon (1992) provide derivation of this derivative which is convenient for computational purposes.

3.3. Numerical solutions to the models

In this section we present the simulated series for the models discussed above. First, a short note should be made on the parameterization of the model. The values of the parameters used in the simulations except for the productivity parameters A and $\tilde{A}$ are similar to those of Marcet and Marimon (1992). This concerns all the models considered throughout the paper. The choice of values for the depreciation rate of the capital (δ) and the discount factor (β) allows to interpret

one period as a year. The values of the parameters are summarized in Table 1.

[insert Table 1 about here.]

A note on the weight λ in the planner's problem should be made. In all the reported simulations the value of λ is set to make expected discounted transfers at $t = 0$ equal to zero. This would ensure that the series reported corresponds to the equilibrium contract.

[insert Figure 1 about here.]

The simulation results for the environment with full enforcement are presented in Figure 1. These results will be compared with those obtained in the autarkic environment (see Figure 2 and 2). The initial value of capital stock in the domestic sector is set to one, while the foreign operated sector is initially assumed to be nonexistent.¹⁶

[insert Figure 2 and 2 about here.]

The results can be summarized in the following way. First, as expected, the consumption of the risk-averse agent in the PO environment is constant both in the steady state and along the transition. All the risk is born by the risk neutral agent, which is also reflected in the volatility of the transfers in the steady state.

Second, under full enforcement the developing country borrows heavily during the initial periods in order to boost investment in both sectors of the economy. Due to the access to external financing, the mean growth rate of output raises from 2.4% to 8.4% during the first 15 periods, and from 1.4% to 3.8% during the first 35 periods.

Third, during the initial periods the investment rates under PO environment are significantly higher than those in the autarky. Under full enforcement, as the capital accumulates in both sectors the investment rates decline. The opposite is observed in the autarkic environment. Higher investment level in the foreign sector than that of the domestic is due to the lower initial capital stock in the former. Remarkably, in the steady state the investment rates under PO environment are more volatile than those in the autarky.

¹⁶This assumption is made to make Autarky directly comparable with other environments. In addition, as in Marcet and Marimon (1992) we assume that the initial capital stock in the Autarkic environment equals to one.

Finally, under full enforcement access to external financial opportunities results in a welfare gain equivalent to a 92% "increase in consumption". By "increase in consumption" we refer to a permanent increase in consumption that would equate the present value under the autarky with the present values achieved under other environments

Remarkably, all of the results reported for the PO environment are also applicable to the model with limited commitment corresponding to Program 2. The implication of this finding is that technological gains from external financing opportunities may eliminate the default risk.

A comment should be made on this finding according to which the solutions to the case of full enforcement and limited enforcement coincide. The fact that participation constraint turns out to be never binding can be driven by the assumption of the punishment in case of deviation from the optimal plan, which is extremely severe. Should the country default it will lose not only the technological advantage and capital accumulated in the newly opened sector but also a possibility to develop this sector on its own. In the remaining of the paper we will address the issue of default punishment which might give some qualitatively different results.

4. The Main Model: Two-sector Autarky and Limited Enforcement

In this section, we will modify the assumption concerning the punishment incurred by the developing country in case of deviation from the optimal plan. It will be assumed that failure to follow the plan would result in the loss of the technological advantage in the newly opened sector¹⁷. However, the newly open sector will remain productive with the productivity level of the domestically operated sector. Furthermore, the country will preserve the accumulated capital in both sectors. In this formulation, the autarky would be given by

Program 3

$$\max_{\{c_t, i_{1t}, i_{2t}\}_{t=0}^{\infty}} E_0 \left[\sum_{t=0}^{\infty} \beta^t u(c_t) \right]$$

subject to

$$c_{1t} + i_{1t} + i_{2t} = f(k_{1t}) + f(k_{2t}), \quad (38)$$

$$k_{jt+1} = (1 - \delta)k_{jt} + g(i_{jt}, \theta_{t+1}), \text{ for } j = 1, 2 \quad (39)$$

¹⁷This assumption is close in spirit to those of Cohen and Sachs (1986) or Eaton and Gersovitz (1984) where foreign debt repudiation results in permanent loss of productive efficiency.

with $c_{1t} \geq 0, i_{1t}, i_{2t} \geq 0, k_{10}, k_{20}, \theta_0$ given.

The arguments from the standard dynamic programming will ensure the existence of the time invariant policy functions $i_1(k_1, k_2, \theta), i_2(k_1, k_2, \theta), c(k_1, k_2, \theta)$ and a value function $V^{a2}(k_1, k_2, \theta)$. Hence, the reservation value for the agent 1 at time t is the utility of the autarkic solution $V^{a2}(k_{1t}, k_{2t}, \theta_t)$ given the capital stock accumulated in the domestically operated sector k_{1t} , the capital stock of the newly opened sector k_{2t} and the productivity shock θ_t .

Under these less stringent assumptions on the default punishment, the optimal allocations can be found by solving the following planner's problem with $\lambda \in \mathbb{R}_+$ and the participation constraint imposed on agent 1.

Program 4

$$\max_{\{c_{1t}, \tau_t, i_{1t}, i_{2t}, k_{1t}, k_{2t}\}_{t=0}^{\infty}} E_0 \left[\sum_{t=0}^{\infty} \beta^t [\lambda u(c_{1t}) + (-\tau_t)] \right]$$

subject to

$$c_{1t} - \tau_t + i_{1t} + i_{2t} = f(k_{1t}) + F(k_{2t}), \quad (40)$$

$$k_{jt+1} = (1 - \delta)k_{jt} + g(i_{jt}, \theta_{t+1}), \text{ for } j = 1, 2 \quad (41)$$

$$E_t \left[\sum_{i=0}^{\infty} \beta^i u(c_{1t+i}) \right] \geq V^{a2}(k_{1t}, k_{2t}, \theta_t), \quad (42)$$

with $c_{1t} \geq 0, i_{1t}, i_{2t} \geq 0, k_{10}, k_{20}, \theta_0$ given.

Once again, in the above framework, the steady state distributions of capital will differ under full and limited enforcement due to the technology transfers. This feature would distinguish the present setup from the framework of Marcet and Marimon (1992) as far as the growth incentives for integration are concerned.

Similar to Program 2, the present problem can be cast into recursive framework the solution to which will be obtained from studying the saddle point functional equation. Denoting γ_{1t} and γ_{2t} the Lagrange multipliers of the constraints (41), the first order conditions for this problem become:

$$(\lambda + M_t) u'(c_{1t}) = 1,$$

$$-1 - \beta E_t \left[\gamma_{jt+1} \frac{\partial g(i_{jt}, \theta_{t+1})}{\partial i_{jt}} \right] = 0, \text{ for } j = 1, 2,$$

$$f'(k_{1t}) - \mu_t \frac{\partial V^{a2}}{\partial k_{1t}}(k_{1t}, k_{2t}, \theta_t) + \gamma_{1t} - \beta(1 - \delta)E_t [\gamma_{1t+1}] = 0,$$

$$F'(k_{2t}) - \mu_t \frac{\partial V^{a2}}{\partial k_{2t}}(k_{1t}, k_{2t}, \theta_t) + \gamma_{2t} - \beta(1 - \delta)E_t [\gamma_{2t+1}] = 0,$$

$$E_t \left[\sum_{i=0}^{\infty} \beta^i u(c_{1t+i}) \right] - V^{a2}(k_{1t}, k_{2t}, \theta_t) \geq 0,$$

$$\mu_t \left[E_t \left[\sum_{i=0}^{\infty} \beta^i u(c_{1t+i}) \right] - V^{a2}(k_{1t}, k_{2t}, \theta_t) \right] = 0,$$

in addition to the technological constraints (40)-(42), the law of motion for the co-state variable M_t ,

$$M_t = M_{t-1} + \mu_t, \quad M_{-1} = 0$$

and non-negativity of the Lagrange multiplier $\mu_t \geq 0$.

Substituting the chosen functional forms and simplifying the first order conditions in a manner similar to the one described in footnote 6 yields the following optimality conditions:

$$\mu_t \left[u(c_{1t}) + E_t \left[\sum_{i=1}^{\infty} \beta^i u(c_{1t+i}) \right] - V^{a2}(k_{1t}, k_{2t}, \theta_t) \right] = 0,$$

$$E_t \left[\sum_{i=0}^{\infty} \beta^i u(c_{1t+i}) \right] - V^{a2}(k_{1t}, k_{2t}, \theta_t) \geq 0,$$

$$c_{1t}^\gamma = 1 / (\lambda + \mu_t + M_{t-1}),$$

$$M_t = M_{t-1} + \mu_t,$$

$$(1 + i_{1t})^2 = \beta E_t \left[a(\theta_{t+1} + s) \sum_{j=0}^{\infty} \beta^j (1 - \delta)^j \left(A\alpha(k_{1t+1+j})^{\alpha-1} - \mu_{t+j+1} \frac{\partial V^{a2}(k_{1t+j+1}, k_{2t+j+1}, \theta_{t+j+1})}{\partial k_{1t+j+1}} \right) \right],$$

$$(1 + i_{2t})^2 = \beta E_t \left[a(\theta_{t+1} + s) \sum_{j=0}^{\infty} \beta^j (1 - \delta)^j \left(\tilde{A} \alpha (k_{2t+1+j})^{\alpha-1} - \mu_{t+j+1} \frac{\partial V^{a2}(k_{1t+j+1}, k_{2t+j+1}, \theta_{t+j+1})}{\partial k_{2t+j+1}} \right) \right],$$

$$c_{1t} - \tau_t + i_{1t} + i_{2t} = A k_{1t}^{\alpha} + \tilde{A} k_{2t}^{\alpha},$$

$$k_{jt+1} = (1 - \delta)k_{jt} + a(\theta_{t+1} + s)i_{jt}/(1 + i_{jt}) + b, \text{ for } j = 1, 2$$

in addition to non-negativity of the Lagrange multiplier $\mu_t \geq 0$ and the initial conditions.

5. Characterization of Equilibria

We solve the model in Program 4 with the PEA using an algorithm similar to the one described for the model in Program 2. As before, in all simulations the TFP parameter of the domestic sector (A) was set to one. When it comes to the TFP parameter of the foreign operated sector ($\tilde{A}$), we consider three representative cases which differ in the magnitude of the technological transfers.

The simulation results are summarized in Figures 3-6 and Tables 3-5. We compare three institutional environments: the autarky equilibrium corresponding to Program 3 denoted as "au" in Figures 3-5, Pareto optimum allocation with perfect enforcement denoted as "po", and the equilibrium with limited enforcement corresponding to Program 4 denoted as "pc". For these figures we plot the first 50 periods as representative of the transition from the low level of capital to the steady state, and periods 100 to 200 as representative of the steady state distribution.

5.1. Equilibria with no technological transfers

First, we consider the case with no technological transfers whatsoever, which in terms of TFP's corresponds to $\tilde{A} = A = 1$. Under lack of commitment, the behavior of the developing country is affected by the two opposing forces. On one hand, the country wants to default on its debt, something which would imply switching to autarky and staying there forever. Unlike the autarky assumption of the Program 2, Program 4 implies that the country would still be in a position to develop the foreign sector on its own with the expropriated capital to begin with. The opposing force is the threat of the punishment for defaulting. In this case, it is the loss of possibility to

borrow in order either enhance growth or to smooth consumption against the unforeseen shocks or along the growth path. As before, the characterization of the capital accumulation and transfers during the transition can be obtained only from the numerical solutions, which are summarized in Figure 3 and Table 3.

[insert Figure 3 and Table 3 about here.]

An important feature of this case is that the steady state distributions of capital are quite similar across all the three environments, in both sectors. They are actually identical in the PC and PO environments as are the distributions of the corresponding investment rates. As reported in Table 3, the steady state capital stock in the autarky environment is slightly higher on average than in the other environments in either of the sectors. The reason for that is that in autarky the country has to self-insure against the cyclical fluctuations of output and the only source of self-insurance is the capital.

In each of the sectors, the investment is more volatile under full enforcement than under the autarky. This feature is similar to the one reported by Marcet and Marimon (1992), and represents an example where an increase in volatility of investment is desirable.

Despite absence of any technological spillovers, the positive effect of the access to external financing on growth is rather substantial under full enforcement. The growth rates go from 2.5 to 3% during the first 15 periods. Yet, this effect practically disappears once the assumption of perfect enforceability of contracts is relaxed. The overall gains, measured as permanent increase in consumption that would equate the present value under the autarky with the present values achieved under other regimes, differ significantly in the PO and PC environments. Failure to perfectly enforce contracts reduces the welfare gains by the factor of 25. In fact, during the transition the consumption paths under autarky and under limited enforcement are very similar. As can be seen from Figure 3, the key difference is that the consumption series under PC is smoother than that under the autarky during the transition. Furthermore, it is outright flat in the steady state while the consumption under autarky keeps fluctuating even in the steady state. Hence, with no technological transfers, the access to the external financing under limited enforcement allows to smooth out variation of output but not keep constant consumption along the transition. The possibility to smooth consumption through external financing results in the minor welfare gain

under limited commitment. As in Marcet and Marimon (1992) enforcement constraints result in negligible transfers and severely reduce growth opportunities.

5.2. *Equilibria with technological transfers of medium magnitude*

The case with the technological transfers of medium magnitude is defined by two characteristic features. First, in the environments which grant access to the external financing, the foreign operated sector is more productive than the domestic one¹⁸. Second, the productivity differences between sectors are low enough to guarantee that the participation constraint is binding in some periods. The key feature of this case is that the productivity benefits introduce a gap between the average steady state capital stocks in the economy with and without external financing. The latter feature makes the punishment for default more severe than in the previous case but not severe enough to eliminate risk of default. The characteristics of the efficient accumulation mechanisms under the three considered institutional setups are summarized in Figure 4 and Table 4.

[insert Figure 4 and Table 4 about here.]

The simulations demonstrate several distinctive features of the setup which encompasses both productivity benefits from external financing and risk of default. These can be summarized in the following way.

First, despite the presence of the default risk in the environment with limited commitment the capital movements from and to the developing country are no longer negligible. This result distinguishes the present setup from both the equilibrium with no technological transfers discussed in the previous section as well as the models of Marcet and Marimon (1992) or Kehoe and Perri (2002). This feature allows to conclude that presence of the default risk is not inconsistent with the capital flows of substantial magnitude.

Second, under limited enforcement the developing country borrows not only in order to smooth cyclical variation in consumption but also in order to invest heavier during the transition and hence foster growth. Remarkably, the borrower boosts investment in all productive sectors and not only those affected by the technological transfers. Once again, in this prediction the current case differs from the case with no technological diffusion, be it two-sector model discussed above or one-sector

¹⁸In terms of sectoral TFPs the case reported here corresponds to $A = 1$ and $\tilde{A} = 1.1$.

framework of Marcet and Marimon (1992). In other words, borrowing with an objective to promote growth can be an equilibrium outcome even in the environment with present risk of default.

Third, the behavior of the consumption path under limited enforcement is rather peculiar. During a few initial periods, the consumption path is flat. Although it is still lower than the consumption level under full enforcement, the series is well above the autarky consumption. In other words, in this environment consumption smoothing along the growth path is no longer absent. As the capital accumulates, the participation constraint starts binding at certain period. After that the consumption in the limited commitment environment rises every time the incentive compatibility constraint binds. As in the case with no technological transfers, the shape of the consumption series reminds that of the autarky. However, during the all the transition periods there is a diminishing wedge between the two series. This can be attributed to the diminishing difference in the accumulated capital stock in the environments with full and limited enforcement. As in the case with no technological diffusion, under limited enforcement the steady state distribution is characterized by a flat consumption schedule which can lie either above or below the autarky path.

Since the default risk is still present during the transition, under limited enforcement the paths of investment, transfers, and capital stock differ from those in the Pareto optimum. Transfers from abroad to the developing country are lower in this case relative to the full enforcement outcome. The investment rates inherit the same feature. In fact, in the sector unaffected by the productivity benefits the investment series falls rather quickly to the autarky level. However, due to the heavy investment during the initial periods, the capital stock under limited enforcement stays above the autarky capital stock during the transition. The latter result holds for all sectors including the domestic one.

Another regularity concerns the average capital stock of the economy in the steady state distribution. As shown by Marcet and Marimon (1992) the capital stock of a country in the environment with limited commitment is lower than that in the autarky. The driving force behind this result is the need to use capital as the only means of self-insurance in the autarkic environment. A similar result is obtained in our framework in the case when no technological diffusion takes place. When the technological transfers are present, however, this conclusion may no longer be true. Since the productivity of the foreign operated sector is higher under limited enforcement than in the autarky, so is the capital stock in the foreign sector. Hence, whether the overall capital stock will be higher

in the autarky than under limited commitment depends on which of the two forces dominates. For instance, in the case with transfers of medium magnitude reported in Table 4, under limited enforcement the capital stock in the domestic sector is lower than that in the autarky. The converse is true for the foreign operated sector.

Some characteristic features of the solutions following from our framework are in line with the documented empirical regularities we began from in Section 1.. For instance, Marcet and Marimon (1992) state that the observed cross-country differences in borrowing patterns and rich structure of capital flows find little explanation in the models of sustained growth. On the contrary, our framework predicts that under limited commitment, the extent to which a developing country will borrow depends on the magnitude of perishable productivity gains associated with external financing relative to the productivity in the autarky.

Another regularity is reported by Gertler and Rogoff (1990) and more recently Lane (2004) who document that the level of foreign debt in the developing countries is positively correlated with their income. This observation is in line with the predictions of our model as well. Indeed, countries which highly benefit from technological transfers in the foreign operated sector will be able not only to increase production due to the productivity gains but also due to the higher capital stock in all sectors. The latter stems from increased investment levels financed through transfers from abroad. Such countries will tend to have both higher income level and higher level of foreign debt.

Our model outperforms existing theories of economic growth in its ability to account for countercyclical behavior of capital inflows to developing countries. The quantitative predictions of our framework and cross-country empirical evidence documented by Kaminsky et al. (2004) is summarized in Figure 5 . The upper histogram reports country correlations between the cyclical components of net capital inflows and real GDP for a sample of 80 developing countries for a period 1960-2003. The lower panel corresponds to the same statistics for the simulated solution of our model.¹⁹ Contrary to the implications of the models of perfect or exogenously restricted capital

¹⁹We report the correlations from the simulated series after removing the secular component with HP filter with the smothing parameter $\lambda = 400$ as suggested by Dolado et al. (1993) for the annual data. Since, we are interested in the behavior of the economy along its transition path, making inference from simulating a long series is not a feasible option. Our strategy is therefore to rely on the logic of Bootstrap methods (see e.g. MacKinnon (2002)) to make better use of the information contained in the simulated series corresponding to the transition. The histogram of country correlations implied by our model is bases on 100.000 Bootstrap iterations.

mobility our framework predicts is that the capital inflows to the developing countries are acyclical. For example, for the same sequence of the exogenous shock our benchmark perfect risk-sharing model predicts the correlation of cyclical component in inflows and output to be -0.86 with the bootstrap standard error of 0.08, while the limited commitment model predicts this statistic to be not significantly different from zero.²⁰

[insert Figure 5 about here.]

In our framework this cyclical behavior of capital flows is partly determined by endogenous incompleteness of the international lending markets. The basic intuition is the following. On one hand, a good realization of the shock increases the value of the autarkic alternative and therefore temptation of the borrower to default. Therefore, an incentive-compatible contract requires a once and for all increase in consumption of the recipient country. On the other hand, an expected increase in productivity of the investment technology incites the borrower to increase investment in every sector of the economy. This increase in consumption and investment is partially financed through an increase in output and partially through capital inflow from abroad. Hence, the cyclical behavior of our model economy is determined by the relative magnitude of these two opposing forces.

The reason that our models fails to predict the procyclical behavior of net capital inflows is that we abstract from a number factors which might matter. One of such factors emphasized in the empirical literature is that government policies tends to be procyclical.²¹

5.3. *Equilibria with technological transfers of high magnitude*

When the magnitude of technological transfers is high enough the defaulter's punishment becomes so severe that the participation constraint turns out to be never binding. Hence, the solution under limited commitment and that under perfect enforcement will coincide. This compels us to reiterate the conclusion obtained earlier from the model with one-sector autarky. Our results suggest that presence of perishable technological benefits associated with external financing may eliminate

²⁰The value of the correlation we obtain is -.13 with the bootstrap standard error of 0.28.

²¹World Bank (2001, p.72) tentatively suggests that "... the procyclical nature of capital flows also reflects volatility induced by a country's own actions—and inactions—through uncertain government policies and, especially, the underdeveloped state of its own financial markets." Empirical evidence on the issue is documented in Kaminsky et al. (2004).

risk of default. The latter is true even though these benefits are enjoyed only by some sectors of the developing economy. The simulation results for the case with technological transfer of high magnitude are presented in Figure 6 and Table 5.

[insert Figure 6 and Table 5 about here.]

One final note will be made concerning the relation between the productivity benefits and the corresponding welfare gains. In the reported example the TFP level in the foreign operated sector ($\tilde{A}$) is set to 1.35. This particular choice is motivated by the desire to find the lowest level of $\tilde{A}$, which would ensure that the participation constraint does not bind. In this case, the welfare gain, measured as a permanent increase in consumption that would equate the present value of utility under the autarky with the present values achieved in the other environments, is large. It corresponds to the increase in consumption of 26%. Notice that these gains are driven by two forces. On one hand, it is higher productivity of the foreign operated sectors under PC than that under autarky which takes the credit. On the other hand, the spillovers increase the default punishment and by that facilitate borrowing during the initial periods in order to foster growth. The importance of the latter force for welfare improvement is more obvious in the case with no transfers reported in Table 3. In the absence of technological diffusion, the failure to enforce contracts results in a welfare loss corresponding to change in consumption of 3.4%. With introduction of moderate technological transfers, corresponding to the TFP level in the foreign operated sector ($\tilde{A}$) of 1.1, the difference between welfare gains under full and limited enforcement falls by more than a half and becomes 1.6%. This reduction of relative welfare benefits can be attributed to an increase in the punishment for default.

To summarize, even moderate perishable technological benefits substantially reduce the negative effect on welfare of the failure to perfectly enforce lending contracts. In other words, in our framework technological transfers play a role of an important enforcement mechanism.

6. Conclusion

The objective of this study was to develop a model of international risk-sharing which would be qualitatively consistent with some features of capital flows to the low- and middle income countries documented in the literature. The model we developed is based on three main premises:

i) international lending contracts are imperfectly enforceable; ii) access to the international financial markets results in technological transfers to a developing country from the rest of the world; iii) some of the productivity gains associated with the access to external financing are perishable.

We consider a two-sector stochastic growth model and compute optimal accumulation mechanisms in the environments which differ in the extent to which the borrowing contracts with the rest of the world are being enforced. Furthermore, we examine different assumptions concerning the defaulter's punishment and their implications for growth, welfare and borrowing patterns. The principal conclusions of this paper can be summarized in the following way:

First, we conclude that the existence of substantial capital flows from the developed to developing countries is not inconsistent with the presence of the default risk. This prediction of our model distinguishes itself from those of the existing international risk-sharing models with imperfect enforcement of lending contracts such as those Marcet and Marimon (1992) and Kehoe and Perri (2002).

Second, we overcome the difficulty that the models of sustained growth have in explaining the rich structure of observed capital flows and the "wide spectrum of borrowing patterns across low- and middle-income countries" (Marcet and Marimon, 1992, p. 221). Our framework predicts that under limited commitment the pattern of capital flows depends heavily on the perishable productivity gains associated with the external financing opportunities. In our framework even moderate technological benefits associated with external financing opportunities may substantially reduce the negative effect on the welfare of the failure to perfectly enforce contracts. In this respect, we conclude that technological transfers may play a role of an important enforcement mechanism. Our model suggests that technological transfers to a developing country from the rest of the world may eliminate risk of default even though they affect only some sectors of the economy.

Third, our model outperforms existing theories of economic growth in its ability to account for countercyclical behavior of net capital inflows to developing countries. Contrary to the implications of the models of perfect or exogenously restricted capital mobility our framework predicts is that the capital inflows to the emerging economies are acyclical. A margin we abstract from in the present inquiry that might be responsible for our failure to predict procyclical inflows is that government policies tend to be procyclical. We leave modeling this feature as an avenue for future research.

Finally, we show that absence of technological diffusion in an environment with limited enforce-

ment of contracts may result in scarce capital flows to developing countries, substantially reduce their growth opportunities and increase volatility of investment. On the other hand, presence of technological transfers in this environment may induce a developing country to use foreign capital to both smooth consumption against unforeseen shocks as well as along the growth path. Moreover, along the transition path the foreign capital will be used to invest more heavily in all the sectors of the economy including those directly unaffected by the technological diffusion. The latter will result in faster growth as well as more substantial welfare gains.

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7. Appendix: Derivations

7.1. Derivation of the necessary conditions in (4), (5) and (6).

Using the arguments of standard dynamic programming (see Stokey et al. (1989)) one can show the existence of the time invariant policy functions $i_1(k_1, k_2, \theta)$, $i_2(k_1, k_2, \theta)$ and a value function $V(k_1, k_2, \theta)$. The Lagrangian for the problem is given by

$$\begin{aligned} \mathcal{L} = & E_0 \sum_{t=0}^{\infty} \beta^t \{ [\lambda u(c_{1t}) + (-\tau_t)] - \lambda_{1t} [c_{1t} - \tau_t + i_{1t} + i_{2t} - f(k_{1t}) - F(k_{2t})] \\ & - \mu_{1t} (k_{1t} - (1 - \delta)k_{1t-1} - g(i_{1t-1}, \theta_t)) - \mu_{2t} (k_{2t} - (1 - \delta)k_{2t-1} - g(i_{2t-1}, \theta_t)) \}, \end{aligned}$$

where λ_{1t} , μ_{1t} and μ_{2t} are the Lagrange multipliers associated with the constraints (1), (2) and (3). The corresponding f.o.c. are given by

$$\lambda u'(c_{1t}) = \lambda_{1t}, \quad (43)$$

$$1 = \lambda_{1t}, \quad (44)$$

$$-\lambda_{jt} + \beta E_t \left[\mu_{jt+1} \frac{\partial g(i_{jt}, \theta_{t+1})}{\partial i_{jt}} \right] = 0, \text{ for } j = 1, 2, \quad (45)$$

$$\lambda_{1t} f'(k_{1t}) - \mu_{1t} + (1 - \delta) \beta E_t [\mu_{1t+1}] = 0, \quad (46)$$

$$\lambda_{1t} F'(k_{2t}) - \mu_{2t} + (1 - \delta) \beta E_t [\mu_{2t+1}] = 0. \quad (47)$$

From the equation (46) using recursive substitution yields

$$\mu_{1t} = E_t \left[\sum_{j=0}^{\infty} (\beta(1 - \delta))^j f'(k_{1t+j}) \lambda_{1t+j} \right].$$

Substituting the latter into (45) and using (44) as well as the law of iterated expectations yields

$$1 = \beta E_t \left[\frac{\partial g(i_{1t}, \theta_{t+1})}{\partial i_{1t}} \sum_{j=0}^{\infty} (\beta(1 - \delta))^j f'(k_{1t+1+j}) \right].$$

The condition (5) is derived using the similar argument from (47),(45), and (44). The condition (6) follows directly from (43) and (44).

7.2. Approximating the value function and its derivative in the one-sector autarky.

The Bellman equation corresponding to the one-sector autarky is given by

$$V^a(k, \theta) = \max_{(c,i) \in A(k)} \left\{ u(c) + \beta E [V^a(k', \theta') \mid \theta] \right\},$$

subject to

$$A(k) = \left\{ (c, i) \in \mathbb{R}_+^2 : c + i = f(k) \right\},$$

$$k' = (1 - \delta)k + g(i, \theta').$$

Denoting by $V'(k, \theta)$ the derivative of the value function with the respect to its first argument, the first order condition for the problem becomes

$$u'(c) = \beta E \left[V^{a'}(k', \theta') \frac{\partial g(i, \theta')}{\partial i} \mid \theta \right]. \quad (48)$$

Applying the theorem of Benveniste - Scheinkman ²² yields the following condition for the derivative:

$$V^{a'}(k, \theta) = u'(c)f'(k) + \beta(1 - \delta)E [V^{a'}(k', \theta') \mid \theta].$$

Rewriting the latter in the sequence form, using recursive substitution and the law of iterated expectations yields

$$V^{a'}(k_t, \theta_t) = E_t \left[\sum_{j=0}^{\infty} (\beta(1 - \delta))^j u'(c_{t+j}) f'(k_{t+j}) \right]. \quad (49)$$

Now, rewriting (48) in the sequence form, using (49) and the law of iterated expectations yields the first order condition for the autarky

$$u'(c_t) = \beta E_t \left[\frac{\partial g(i_{1t}, \theta_{t+1})}{\partial i_{1t}} \sum_{j=0}^{\infty} (\beta(1 - \delta))^j u'(c_{t+1+j}) f'(k_{1t+1+j}) \right]. \quad (50)$$

²²see Stokey et al. (1989) or Marcet and Marimon (1992) for details.

In order to approximate the value function and its derivative the following algorithm can be used. First, parameterize the conditional expectation in (49) as

$$\psi(\omega, k_t, \theta_t) = \exp(P_n(\log(k_t), \log(\theta_t))),$$

where P_n is a polynomial of degree n . Then, run a non-linear regression, which for $n = 2$ takes the form:

$$\begin{aligned} Y_t = & \exp(\omega_1 + \omega_2 \log(k_t) + \omega_3 \log(\theta_t) + \omega_4 (\log(k_t))^2 \\ & + \omega_5 \log(k_t) \log(\theta_t) + \omega_6 (\log(\theta_t))^2) + \eta_t, \end{aligned}$$

where the dependent variable Y_t is given by the expression inside the conditional expectation in (49) evaluated at the autarky solution $\{c_t, k_t\}_{t=0}^{\infty}$.

A similar approach can be used to approximate the value function, except the parameterization of the conditional expectation should change to $\psi(\omega, k_t, \theta_t) = -\exp(P_n(\log(k_t), \log(\theta_t)))$ since utility of the agent 1 takes only negative values.

7.3. Derivation of the first order conditions for the two-sector autarky in Program 3.

The dynamic problem corresponding to the autarky with two open sectors is given by

$$\max_{\{c_t, i_{1t}, i_{2t}\}_{t=0}^{\infty}} E_0 \left[\sum_{t=0}^{\infty} \beta^t u(c_t) \right]$$

subject to

$$c_{1t} + i_{1t} + i_{2t} = f(k_{1t}) + f(k_{2t}), \quad (51)$$

$$k_{jt+1} = (1 - \delta)k_{jt} + g(i_{jt}, \theta_{t+1}), \quad \text{for } j = 1, 2, \quad (52)$$

with $c_{1t} \geq 0, i_{1t}, i_{2t} \geq 0, k_{10}, k_{20}, \theta_0$ given.

The Lagrangian for the problem is given by

$$\begin{aligned} \mathcal{L} = & E_0 \sum_{t=0}^{\infty} \beta^t \{u(c_t) - \lambda [c_{1t} - \tau_t + i_{1t} + i_{2t} - f(k_{1t}) - f(k_{2t})] \\ & - \mu_{1t}(k_{1t} - (1 - \delta)k_{1t-1} - g(i_{1t-1}, \theta_t) - \mu_{2t}(k_{2t} - (1 - \delta)k_{2t-1} - g(i_{2t-1}, \theta_t))\}, \end{aligned}$$

where λ_{1t}, μ_{1t} and μ_{2t} are the Lagrange multipliers associated with the constraints (51) and (52).

The corresponding f.o.c. are given by

$$u'(c_t) = \lambda_t, \quad (53)$$

$$-\lambda_t + \beta E_t \left[\mu_{jt+1} \frac{\partial g(i_{jt}, \theta_{t+1})}{\partial i_{jt}} \right] = 0, \text{ for } j = 1, 2, \quad (54)$$

$$\lambda_t f'(k_{jt}) - \mu_{jt} + (1 - \delta) \beta E_t [\mu_{jt+1}] = 0, \text{ for } j = 1, 2. \quad (55)$$

Using recursive substitution and the law of iterated expectations (55) reduces to

$$\mu_{jt} = \beta E_t \left[\sum_{i=0}^{\infty} (\beta(1 - \delta))^i f'(k_{jt+1+i}) \lambda_{t+i} \right], \text{ for } j = 1, 2,$$

which combined with (53) and (54) yields

$$u'(c_t) = \beta E_t \left[\frac{\partial g(i_{jt}, \theta_{t+1})}{\partial i_{jt}} \sum_{i=0}^{\infty} (\beta(1 - \delta))^i f'(k_{jt+1+i}) u'(c_{t+i}) \right], \text{ for } j = 1, 2.$$

Figure 1.
Efficient accumulation mechanism under full enforcement.

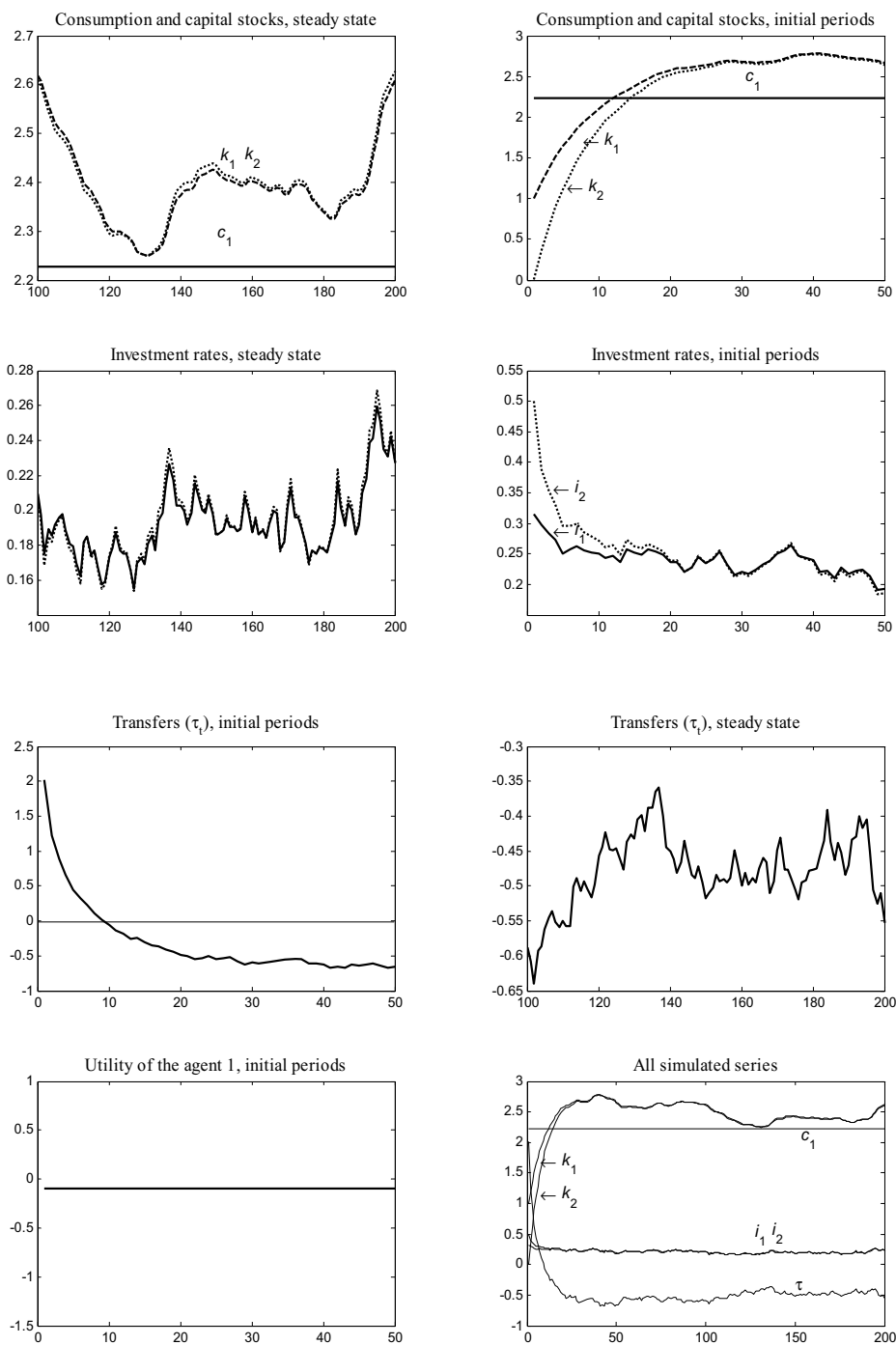


Figure 2.

The model with one-sector autarky: efficient accumulation mechanisms

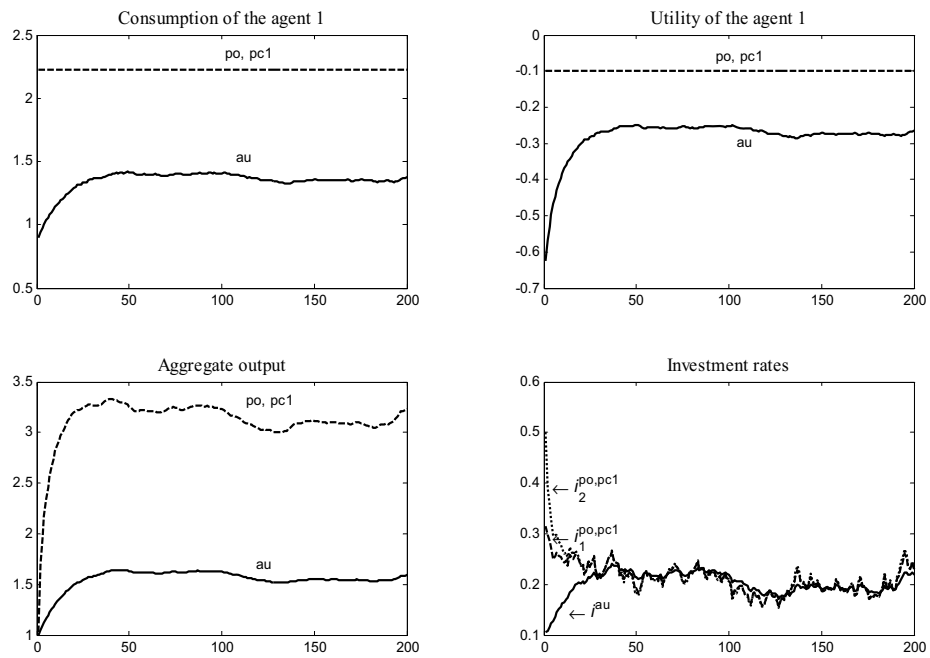


Figure 3.
The model with two-sector autarky: no technological transfers.

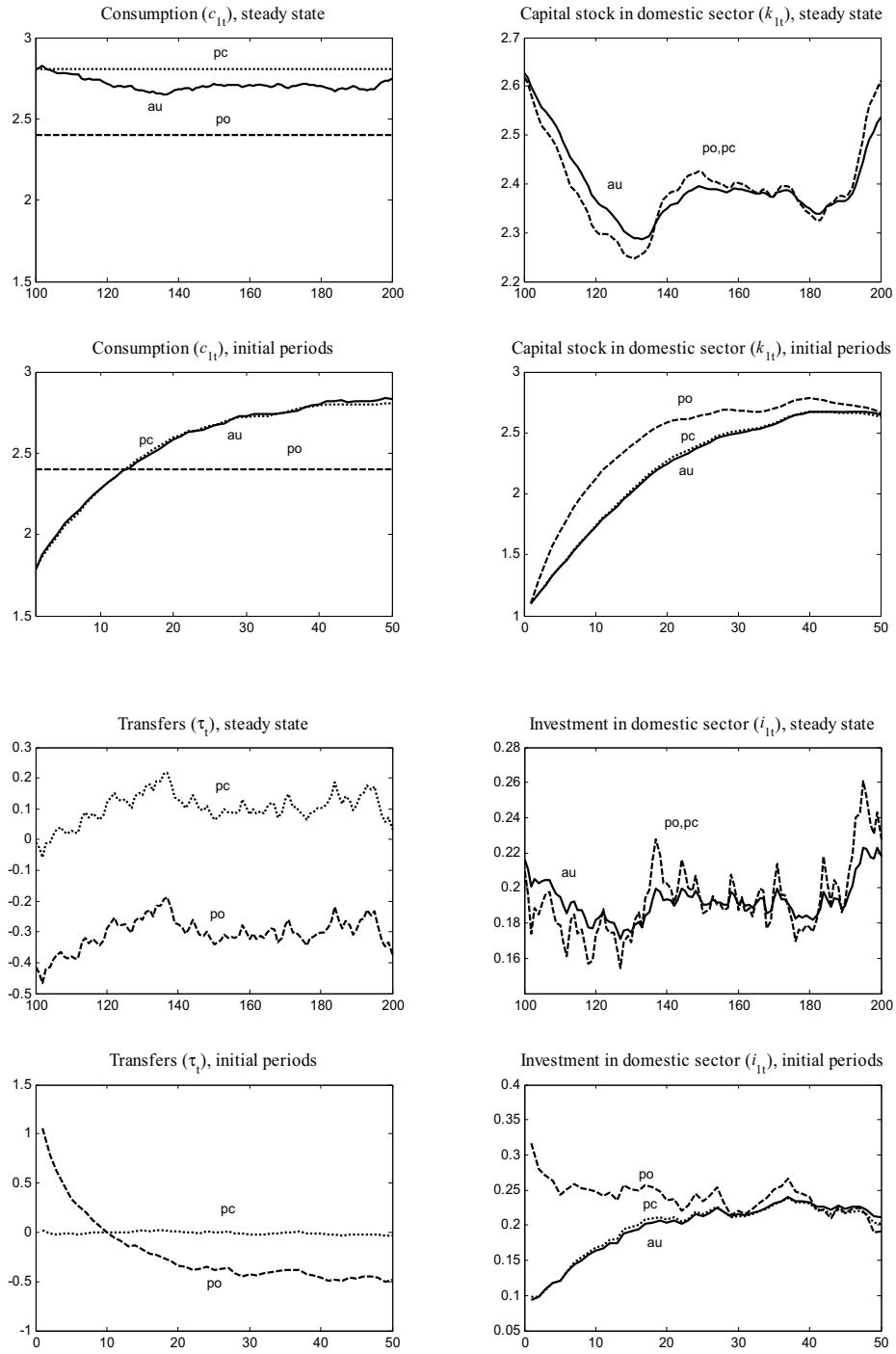


Figure 4.

The model with two-sector autarky: technological transfers of medium magnitude.

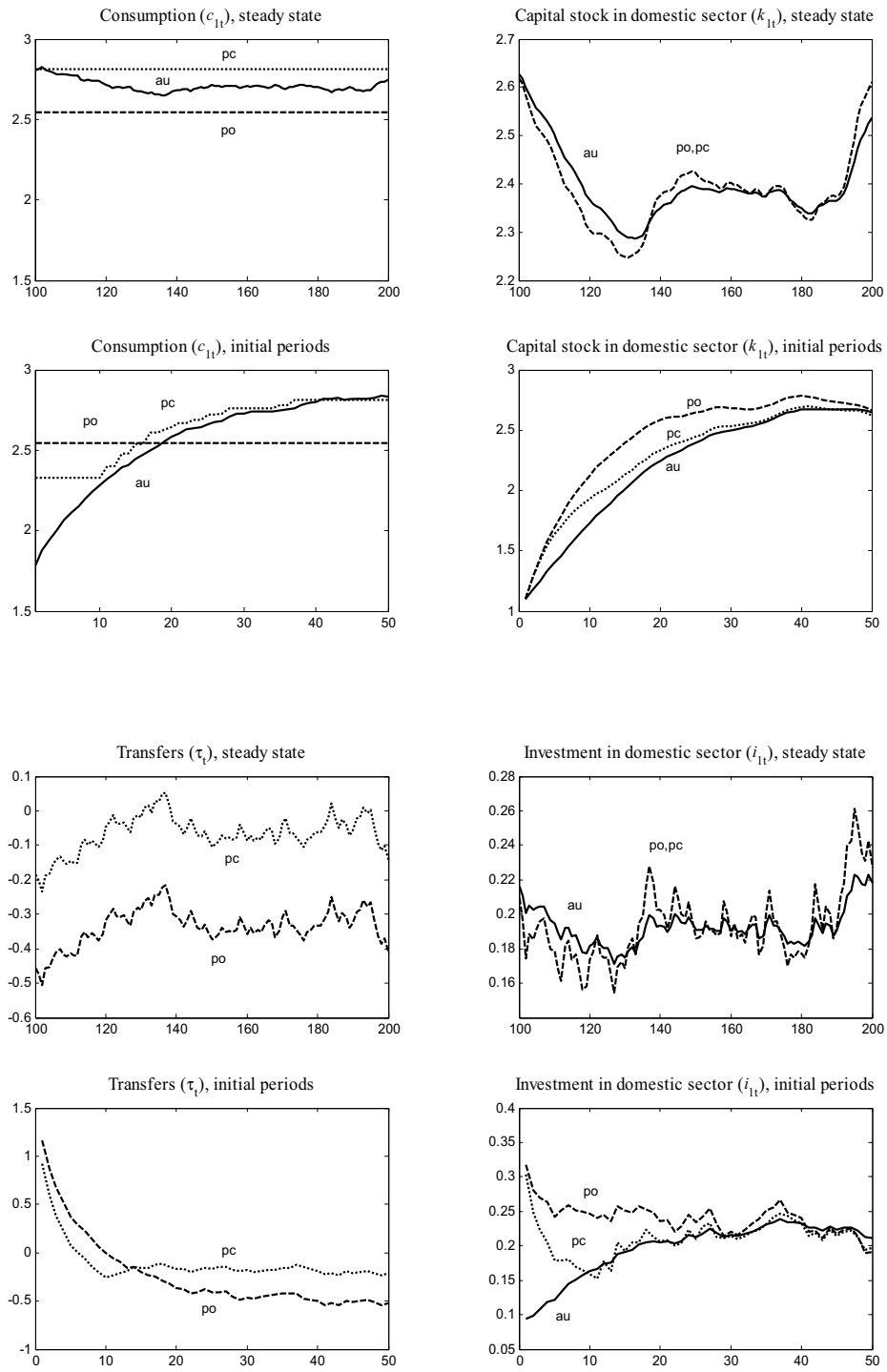


Figure 5.
Histograms of Country Correlations between the Cyclical Components of Net Capital
Inflows and Real GDP: Data (upper panel) and Model Predictions.

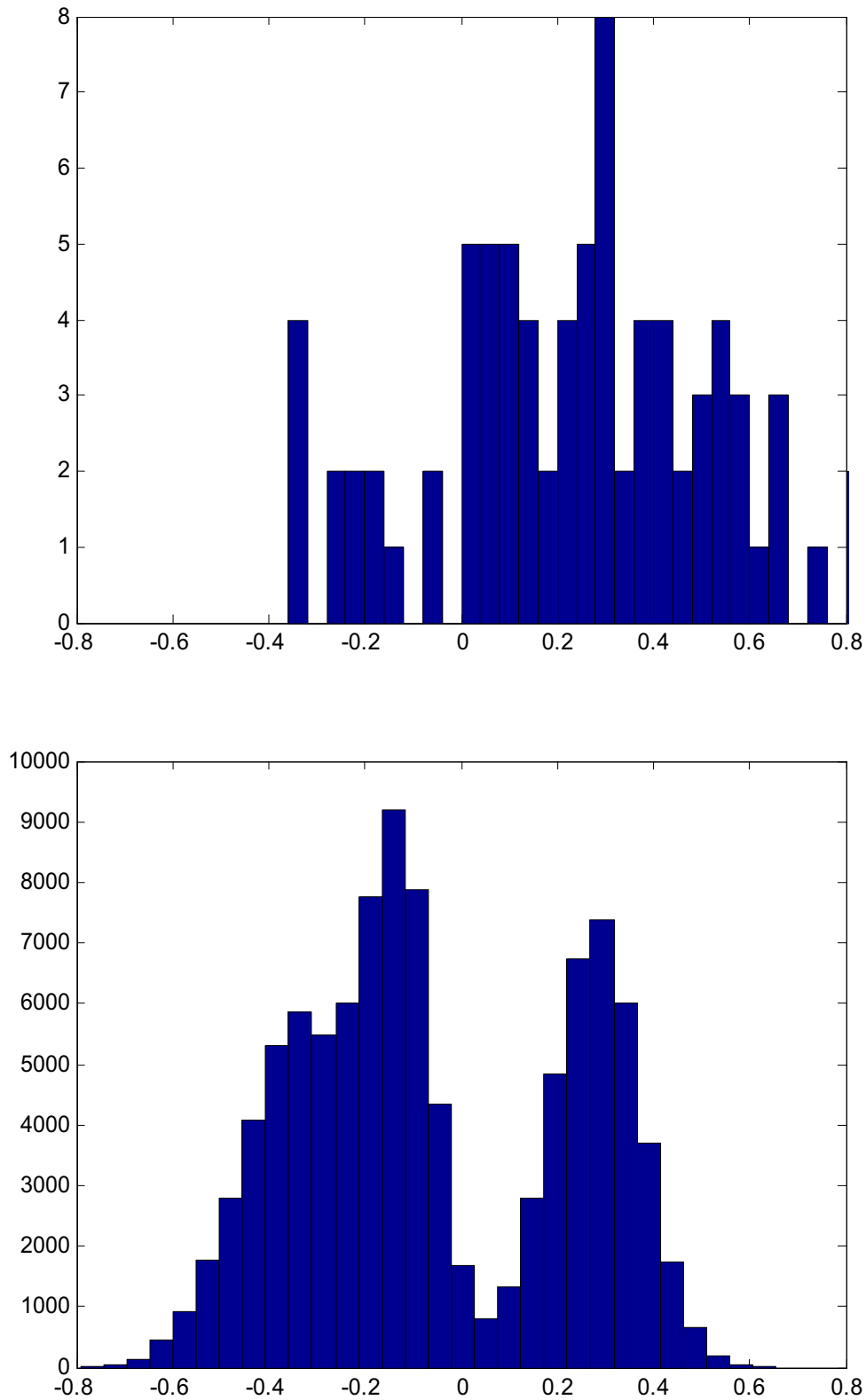


Figure 6.
The model with two-sector autarky: technological transfers of high magnitude.

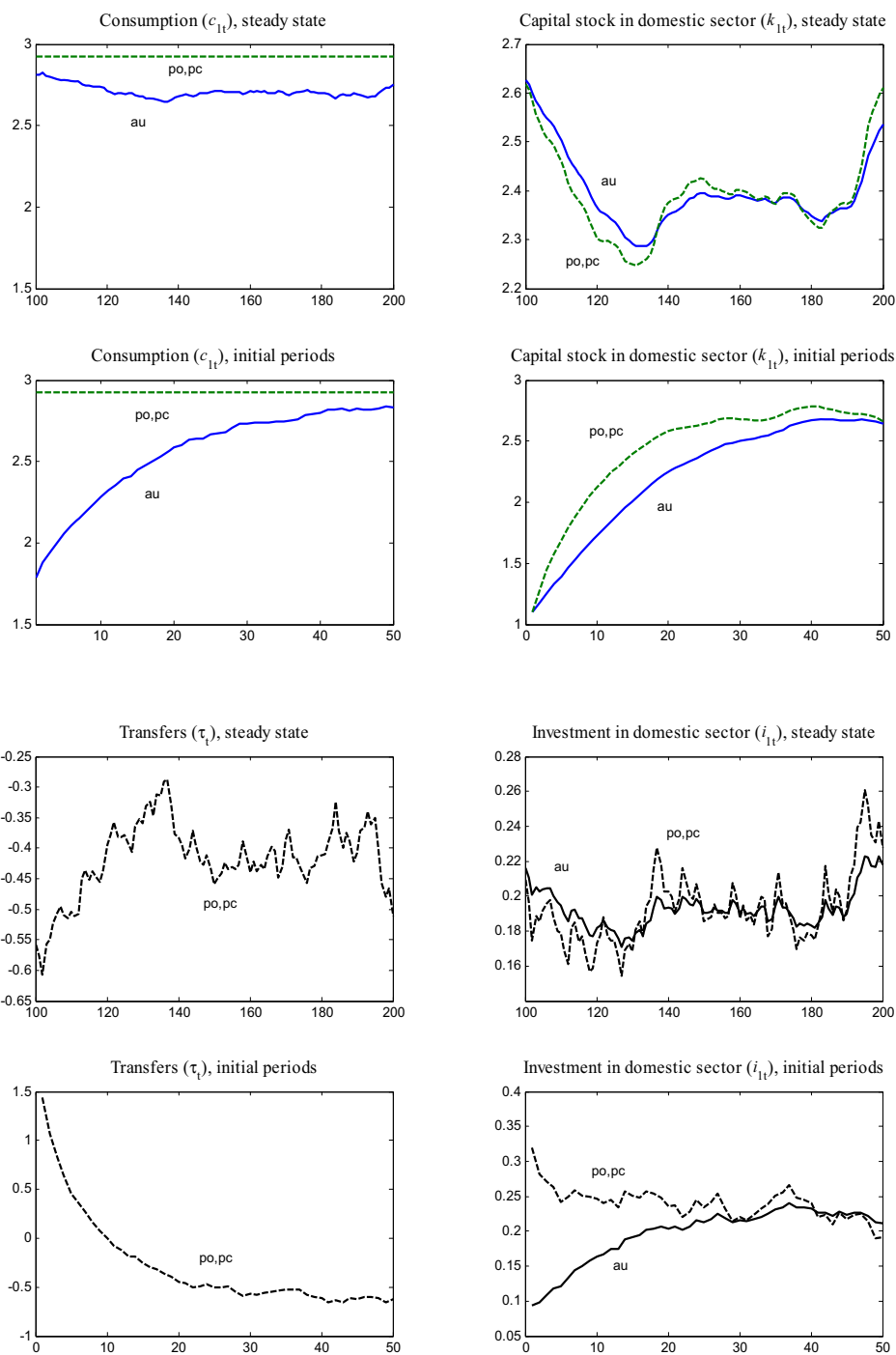


Table 1. Parameterization of the models

Factor share of capital	$\alpha = 0.5$
Risk-aversion parameter of agent 1	$\gamma = -3$
Discount factor	$\beta = 0.95$
Autocorrelation parameter of $\log(\theta_t)$	$\rho = 0.95$
Standard deviation of innovations of $\log(\theta_t)$	$\sigma_\varepsilon = 0.03$
Depreciation rate	$\delta = 0.1$
Constants in the investment functions	$a = 0.6; s = 0.2; b = 0.13$

Note: Throughout the paper the values of the parameters used in the simulations except for the productivity parameters A and $\tilde{A}$ are similar to those of Marcet and Marimon (1992).

Table 2. Simulation results: the models with one-sector autarky ($\tilde{A} = 1.00$)

Model	Utility of the agent 1	Mean of growth rate of output (15 periods)	Mean of growth rate of output (35 periods)	Mean of capital in domestic sector (steady state)	Increase in consumption
AU	-7.44	2.41%	1.38%	2.478	-
PO, PC1	-2.01	8.44%	3.80%	2.467	92.20%

Note: The institutional environments considered are the one-sector autarky corresponding to Program (AU), the environment with perfect enforcement in Program 1 (PO), and the limited commitment environment in Program 2 (PC1). The productivity levels of domestic and foreign operated sectors are set to be identical. The utility of the agent 1 is measured at Time 0 using many independent replications of the model conditioning on $\theta_0 = 1$, and $k_{10} = 1$ in case of autarky and $k_{10} = 1, k_{20} = 0$ in case of the two sector models. "Mean of growth rate of output" refers to the mean across independent realizations during the first 15 and 35 periods respectively. The "Increase in consumptions" refers to the permanent increase in consumption that would equate the present value under the autarky with the present values achieved under other environments.

Table 3. Simulation results: the case with no technological transfers ($\tilde{A} = 1.00$)

Model	Utility of the agent 1	Mean of growth rate of output (15 periods)	Mean of growth rate of output (35 periods)	Mean of capital in domestic/foreign sector (steady state)	Increase in consumption
AU3	-1.861	2.455%	1.381%	2.470 / 2.470	-
PO	-1.734	3.035%	1.463%	2.466 / 2.466	3.58%
PC	-1.856	2.470%	1.384%	2.466 / 2.466	0.14%

Note: The case with no technological transfers corresponds to the setup when the productivity levels of domestic and foreign operated sectors are identical. The institutional environments considered are the two-sector autarky in Program 3 (AU3), the environment with perfect enforcement in Program 1 (PO), and the limited commitment environment in Program 4 (PC). "Mean of growth rate of output" refers to the mean across independent realizations during the first 15 and 35 periods respectively. The utility of the agent 1 is measured at Time 0 using many independent replications of the model conditioning on $\theta_0 = 1$, and $k_{10} = 1.1$, $k_{20} = 0.9$. The "Increase in consumptions" refers to the permanent increase in consumption that would equate the present value under the autarky with the present values achieved under other environments.

Table 4. Simulation results: the case of technological transfers of medium magnitude ($\tilde{A} = 1.10$)

Model	Utility of the agent 1	Mean of growth rate of output (15 periods)	Mean of growth rate of output (35 periods)	Mean of capital in domestic/foreign sector (steady state)	Increase in consumption
AU3	-1.861	2.455%	1.381%	2.470 / 2.470	-
PO	-1.542	3.161%	1.523%	2.467 / 2.641	9.87%
PC	-1.588	2.787%	1.462%	2.465 / 2.639	8.26%

Note: The case with no the case of technological transfers of medium magnitude corresponds to the setup when the productivity levels of foreign operated sectors is higher than that of the domestic sector. However, the productivity differences are not big enough to eliminate risk of default in the environment with limited commitment. The rest is similar to Table 3.

Table 5. Simulation results: the case of technological transfers of high magnitude ($\tilde{A} = 1.35$)

Model	Utility of the agent 1	Mean of growth rate of output (15 periods)	Mean of growth rate of output (35 periods)	Mean of capital in domestic/foreign sector (steady state)	Increase in consumption
AU3	-1.861	2.455%	1.381%	2.470 / 2.470	-
PO	-1.168	3.450%		2.467 / 3.016	26.22%
PC	-1.168	3.450%		2.467 / 3.016	26.22%

Note: The case with no the case of technological transfers of high magnitude corresponds to the setup when the productivity levels of foreign operated sectors is higher than that of the domestic sector. Moreover, the productivity differences are big enough to eliminate risk of default in the environment with limited commitment. The rest is similar to Table 3.